CHARM CONTENT OF A PROTON IN COLLINEAR PARTON MODEL AND IN K_T-FACTORIZATION APPROACH *

V.A.Saleev and D.V.Vasin
Samara State University
Samara 443011, Russia
E-mail: saleev@ssu.samara.ru and vasin@ssu.samara.ru

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Abstract

It is shown that the difference between the c-quark proton SF's calculated in the k_T-factorization approach using different unintegrated gluon distribution functions is the same order as the difference between results obtained in the parton model and in the k_T-factorization approach.

1 Introduction

The result of a study for the internal structure of a proton in the process of the lepton deep inelastic scattering (DIS) can be presented in terms of a

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proton structure function (SF) $F_2^p(x_B, Q^2)$ as a function of $Q^2 = -q^2$ and $x_B = Q^2/2(pq)$, where q is the exchange photon 4-momentum and p is the proton 4-momentum. In a process of the charmed quark leptoproduction the charmed content of the proton structure function $F_{2c}^p(x_B, Q^2)$ is probed. The recent relevant measurings by the H1 [1] and the ZEUS [2] Collaborations at the HERA ep-collider include the following kinematic region: $1.8 < Q^2 < 130$ GeV^2 and $5 \cdot 10^{-5} < x_B < 2 \cdot 10^{-2}$.

The charmed quark SF has been studied in the framework of DGLAP [3] and BFKL [4] dynamics. Usually, the c-quark SF $F_{2c}^p(x_B, Q^2)$ is calculated via the amplitude which described by the quark box diagrams. This type of a calculation for the $F_{2c}^p(x_B, Q^2)$ is presented in the talk by A.Kotikov [5].

Here we use another method which is based on a direct calculation of the total $c\bar{c}-$production cross section in the electron DIS. In a such way, we have obtained the c-quark distribution function $C_p(x_B, Q^2)$ which is connected with the c-quark SF as follows:

$$F_{2c}^p(x_B, Q^2) = 2e_c^2 x_B C_p(x_B, Q^2). \tag{1}$$

2 Electroproduction cross section

In the framework of the parton model and the one photon exchange approximation the charmed quark production cross section in the electron DIS can be presented as a convolution of the c-quark proton distribution function and the electron – c-quark partonic cross section:

$$d\sigma(ep \to ecX) = \int dx_B C_p(x_B, Q^2) d\hat{\sigma}(ec \to ec). \tag{2}$$

The doubly differential cross section can be presented as follows:

$$\frac{d\sigma}{dx_B dQ^2}(ep \to ecX) = C_p(x_B, Q^2) \frac{\overline{|M(ec \to ec)|^2}}{16\pi(x_B s)^2}, \tag{3}$$

where $s = (p_e + p)^2$, p is the proton 4-momentum, p_e is the electron 4-momentum. The squared amplitude of an elastic $ec-$scattering has the following form:

$$\overline{|M(ec \to ec)|^2} = 2\frac{e^4 e_c^2}{Q^4}(x_B s)^2 \left(y^2 - 2y + 2 - \frac{2m_c^2 y^2}{Q^2} \right), \tag{4}$$

where $y = Q^2/(x_B s)$. From (1), (3) and (4) we can obtain the master formula

$$F_{2c}^p(x_B, Q^2) = x_B Q^4 \frac{d\sigma}{dx_B dQ^2}(ep \to ecX) / \left(\pi\alpha^2 (y^2 - 2y + 2 - \frac{2m_c^2 y^2}{Q^2}) \right). \tag{5}$$

At the high energy the dominant mechanism of the c-quark electroproduction on a proton is the photon-gluon fusion. In the leading order approximation for the QCD running constant α_s the relevant subprocess is $e + g \to e + c + \bar{c}$.

In the conventional collinear parton model it is suggested that hadronic cross section, in our case $\sigma(ep \to ecX, s)$, and the relevant partonic cross section $\hat{\sigma}(eg \to ec\bar{c}, \hat{s})$ are connected as follows:

$$\sigma^{PM}(ep \to ecX, s) = \int dx G(x, \mu^2) \hat{\sigma}(eg \to ec\bar{c}, \hat{s}), \tag{6}$$

where $\hat{s} = xs$, $G(x, \mu^2)$ is the collinear gluon distribution function in a proton, x is the gluon fraction of a proton momentum, μ^2 is the typical scale of a hard process. The μ^2 evolution of the gluon distribution $G(x, \mu^2)$ is described by DGLAP evolution equation [3]. In the k_T-factorization approach hadronic and partonic cross sections are related by the following condition [6]:

$$\sigma^{KT}(ep \to ecX) = \int \frac{dx}{x} \int d\vec{k}_T^2 \int \frac{d\phi}{2\pi} \Phi(x, \vec{k}_T^2, \mu^2) \hat{\sigma}(eg^* \to ec\bar{c}, \hat{s}) \tag{7}$$

where $\hat{\sigma}(eg^* \to ec\bar{c}, \hat{s})$ is the c-quark production cross section on the off mass-shell ("reggeized") gluon, $k^2 = -\vec{k}_T^2$, $\hat{s} = xs - \vec{k}_T^2$, ϕ is the azimuthal angle in the

transverse XOY plane between vectors $\vec{k}_T$ and the fixed OX axis ($\vec{p}_e$ and $\vec{p}_e' \in XOZ$).

The unintegrated gluon distribution function $\Phi(x, \vec{k}_T^2, \mu^2)$ satisfies the BFKL evolution equation [4]. At the $x \ll 1$ the off mass-shell gluon has dominant longitudinal polarization along a proton momentum and the gluon polarization four-vector is written as follows [6] $\varepsilon^\mu(k) = k_T^\mu/|\vec{k}_T|$.

Our calculation in the parton model was done using the GRV [7] and the CTEQ5L [8] parameterizations for a collinear gluon distribution function $G(x, \mu^2)$. In case of the k_T-factorization approach we use the following parameterizations for an unintegrated gluon distribution function $\Phi(x, \vec{k}_T^2, \mu^2)$: JB by Bluemlein [9], JS by Jung and Salam [10], KMR by Kimber, Martin and Ryskin [11]. We compared these parameterizations directly in our recent paper [12].

Finally, in the k_T-factorization formalism the doubly differential cross section for the process $ep \to ecX$ can be written as follows:

$$\frac{d\sigma^{KT}}{dx_B dQ^2} = \frac{y}{x_B} \int dp_{cT} d\phi_c d\eta_c d\vec{k}_T^2 \frac{d\phi}{2\pi} \frac{p_c p_{cT}}{E_c} \frac{\overline{|M(eg^* \to ec\bar{c})|^2}}{256\pi^4 (y - a_1)(xs)^2} \Phi(x, \vec{k}_T^2, \mu^2), \quad (8)$$

where $p_c = (E_c, \vec{p}_c)$ is the c-quark 4-momentum, η_c is the c-quark pseudorapidity, ϕ_c is the azimuthal angle between OX axis and vector $\vec{p}_{cT}$, $a_1 = 2(pp_c)/s$, $b_1 = 2(p_e p_c)/s$ and

$$x = (\vec{k}_T^2 + Q^2 + y b_1 s + 2(\vec{q}_T \vec{k}_T) - 2(\vec{p}_{cT} \vec{k}_T) - 2(\vec{q}_T \vec{p}_{cT}))/((y - a_1)s). \quad (9)$$

We use the following approximations for gluon 4-momentum $k^\mu = xp^\mu + k_T^\mu$, where $k_T^\mu = (0, \vec{k}_T, 0)$.

In the parton model one has $\vec{k}_T = 0$ and

$$\frac{d\sigma^{PM}}{dx_B dQ^2} = \frac{y}{x_B} \int dp_{cT} d\phi_c d\eta_c \left(\frac{p_c p_{cT}}{E_c}\right) \frac{\overline{|M(eg \to ec\bar{c})|^2}}{256\pi^4 (y - a_1)(xs)^2} xG(x, \mu^2), \quad (10)$$

where

$$x = (Q^2 + yb_1 s - 2(\vec{q}_T \vec{p}_{cT}))/((y - a_1)s). \quad (11)$$

The obtained results (Fig. 1) demonstrate agreement between our predictions and the recent data for the $F_{2c}^p(x_B, Q^2)$ from HERA [2]. However, we see that the difference between the c-quark proton SF's calculated in the k_T-factorization approach using different unintegrated gluon distribution functions is the same order as than the difference between results obtained in the parton model and in the k_T-factorization approach.

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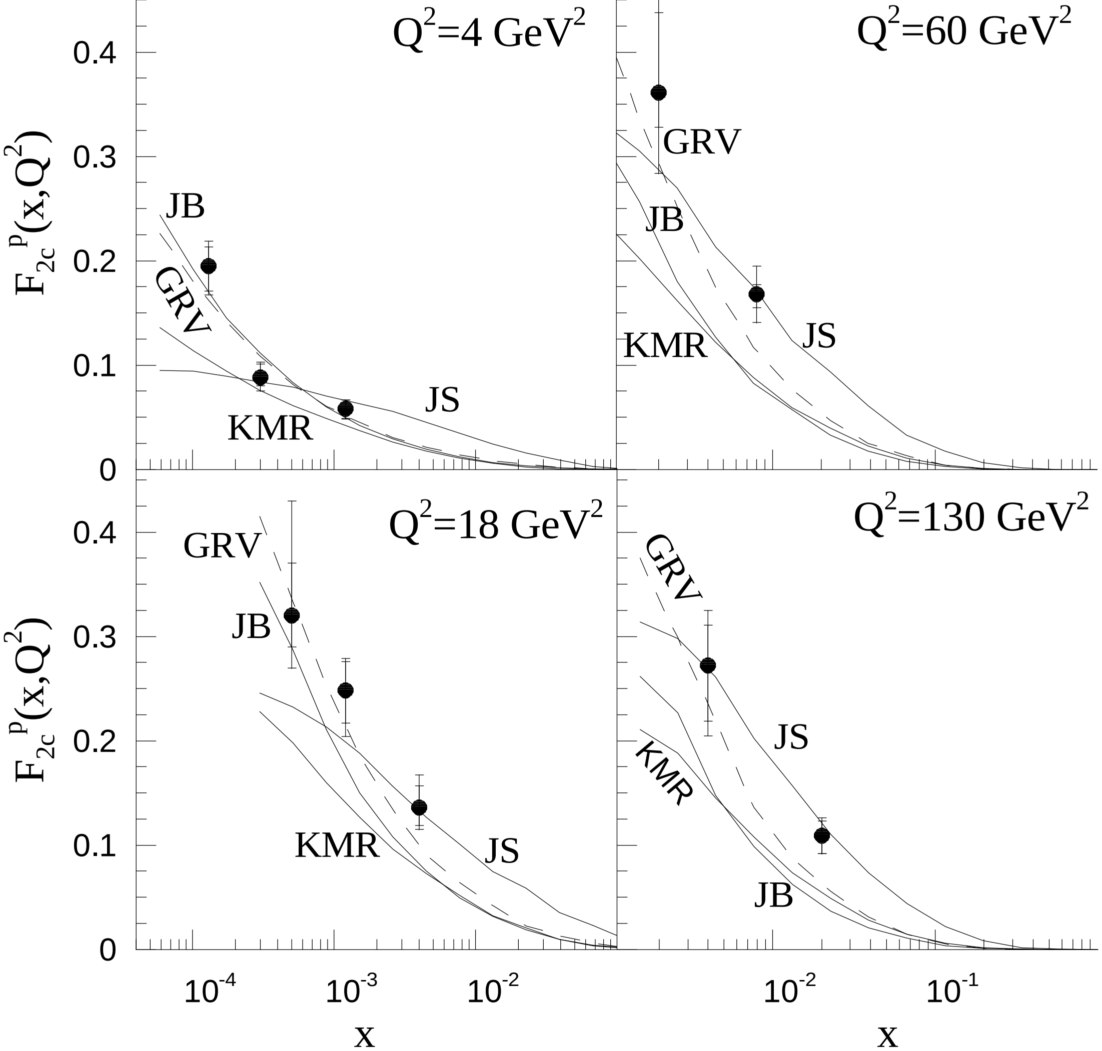
Figure 1: The SF $F^p_{2c}(x_B, Q^2)$ as a function of x_B at the Q^2=4, 18, 60 and 130 GeV^2 compared to ZEUS data



Q^2=4 GeV^2
Q^2=60 GeV^2
Q^2=18 GeV^2
Q^2=130 GeV^2
$F_{2c}^{\ p}(x,Q^2)$
JB
GRV
KMR
JS
0
0.1
0.2
0.3
0.4
10^{-4}
10^{-3}
10^{-2}
10^{-1}
x